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'Stoffenmanager', a Web-Based Control Banding Tool Using an Exposure Process Model

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In the scope of a Dutch programme to reinforce the working conditions policy on hazardous substances, an internet-based tool was developed to help small- and medium-sized companies to handle hazardous substances with more care. The heart of this tool, called the Stoffenmanager, is a risk banding scheme. It combines a hazard banding scheme similar to that of COSHH Essentials and an exposure banding scheme based on an exposure model originally presented by Cherrie *et al*. (1996) and further developed by Cherrie and Schneider (1999). The exposure model has been modified to allow non-expert users to understand and use the model. Exposure scores are calculated based on categorization of determinants of emission, transmission and immission. These exposure scores are assigned to exposure bands. The comparison of exposure bands and hazard bands leads to a risk band or priority band. Following the evaluation of the priority of tasks done with products, generic exposure control measures can be evaluated for their possibility to lower the risks. Relevant control measures can be put into an action plan and into workplace instruction cards. The tool has several other functionalities regarding registration and storage of products. The exposure model in the Stoffenmanager leads to exposure scores. These have been compared with measured exposure levels. The exposure scores correlated well with measured exposure levels. The development of the Stoffenmanager has facilitated a whole range of further developments of useful tools for small- and medium-sized enterprises.

Keywords: exposure estimation; risk assessment; risk management

BACKGROUND AND INTRODUCTION

The rules for assessing and managing risks of dangerous substances in the workplace have been laid down in several European Directives, such as the Framework Directive (Council Directive 89/391, 1989), the Carcinogens Directive (Council Directive 90/394/EEC, 1990) and the Chemical Agents Directive (Council Directive 98/24/EC, 1998). However, keeping these rules is not easy, as several authors from different European Union member states have stressed (Maidment, 1998; Nieminen, 1998; Tijssen and Links, 2002; Balsat *et al.*, 2003). Further research on chemical risk factors and risk management in small and medium-sized enterprises (SMEs) are among the top priorities in Europe in relation to occupational safety and health (European Agency for Safety and Health at Work, 2000). The Dutch Ministry of Social Affairs and Employment has established a 4-year programme to assist SMEs in reinforcing the working conditions policy on hazardous substances, the so-called 'VASt programme' (http://vast.szw.nl). Industry sectors, product chains and companies could obtain financial support for action plans aimed at implementation of improvements through this programme. Furthermore, a set of projects has been carried out to provide the industry with effective tools to assess and control exposure to dangerous substances.

The control banding tool for inhalation exposure was developed to help companies without specific expertise in chemical risk assessment to prioritize their

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potential risks of chemicals and to indicate the types of exposure controls that could lower these risks. Such a tool classifies exposure situations into risk, control or priority bands, based on classification systems for the hazards of the substances and the exposure and controls in the situations. The development of the tool started with an inventory of available approaches in Europe. A number of approaches were studied, including control of substances hazardous to health (COSHH) Essentials (Russell *et al.*, 1998), a 'safety check' developed by the German Berufsgenossenschaftliche Institut für Arbeitssicherheit (Kittel *et al.*, 1996), a 'support making decision tool' in development in France (Vincent and Bonthoux, 2000) and a method for 'Chemische Arbeitsstoffe' by the Austrian Allgemeine Unfallversicherungsanstalt (AUVA, date unknown).

The instruments were all evaluated against the following criteria:

1. directed at hazardous substances,
2. directed at the SME employer,
3. part of a larger improvement process and
4. relevant for risk assessment and control.

All instruments appeared to offer useful elements. However, it was decided that a new instrument would best fit the needs of SMEs in The Netherlands. Therefore, instead of 'simply' translating one of the foreign instruments, a new instrument was built, based on previous work published by other groups. In this way, it represents a combination of useful elements from different sources.

Briefly, the 'hazard banding' part of the tool is based on COSHH Essentials (Brooke, 1998), the exposure model on an approach published by Cherrie *et al.* (1996) and Cherrie and Schneider (1999) and the 'risk banding' part is made by combining hazard bands with exposure bands resulting from the exposure model. The structure of the Stoffenmanager was derived from a software tool (ChemAudit) which assists SMEs in controlling risks due to exposure to hazardous substances (Heussen *et al.*, 2002).

In this publication, the priority ranking of the Stoffenmanager version 3.5 will be briefly described. The focus of the publication is on the qualitative scoring part of the inhalation exposure model, because this is the most innovative part of the tool. This version of the Stoffenmanager has been evaluated using a large-scale validation study (Tielemans *et al.*, 2008). It also includes a quantification of exposure that is also described in Tielemans *et al.* (2008). Some (future) developments of Stoffenmanager will be briefly indicated in this publication.

The Stoffenmanager also contains a risk banding module for dermal exposure. The core of this module is the RISKOFDERM Toolkit (Goede *et al.*, 2003; Oppl *et al.*, 2003; Schuhmacher-Wolz *et al.*, 2003; Warren *et al.*, 2003), which is incorporated in the Stoffenmanager. Because of the integration in the total tool, some questions that are in the RISKOFDERM Toolkit do not appear in the dermal part of Stoffenmanager because they are already covered in the general hazards part or the inhalation exposure part. This does not influence the actual risk assessment for dermal exposure. The dermal feature will not be discussed further in this paper.

GENERAL FRAMEWORK OF THE STOFFENMANAGER

The basic element of the Stoffenmanager is risk banding. However, some other useful elements are included as well. The Stoffenmanager is a web-based tool and is currently available in English and Dutch (www.stoffenmanager.nl). The user enters data in web-based forms. Data are kept confidential and can only be accessed and used by the user by logging in with his user name and password. Use of the Stoffenmanager is free of charge. The general structure of the tool is presented in Fig. 1.

Input of basic data

The Stoffenmanager prioritizes exposure to products. These may be preparations (e.g. a paint), but can also be pure substances. Basic data on the products can be entered manually or (largely) from a database with product information, using a standard exchange format. Part of the information, such as the Risk and Safety phrases according to the safety data sheet (SDS), is not directly used in the risk banding model, but is used for other features, e.g. for the derivation of more user-friendly workplace instruction cards based on the information in the SDS. The following information has to be entered:

1. Name of the product
2. Publication date of the SDS
3. Whether the substance is a solid or a liquid
    - For a solid: the dustiness
    - For a liquid, the vapour pressure
4. Supplier of the product
5. Departments in which the product is used
6. Composition of the product, according to the SDS
7. Hazard categories (i.e. symbols according to the SDS)
8. Personal protective equipment (PPE) and ventilation needed (according to the SDS)
9. Risk and safety phrases [R/S phrases for the product (i.e. not for the individual components), according to the SDS]

The vapour pressure for products (i.e. not pure substances) as mentioned on the SDS is used,

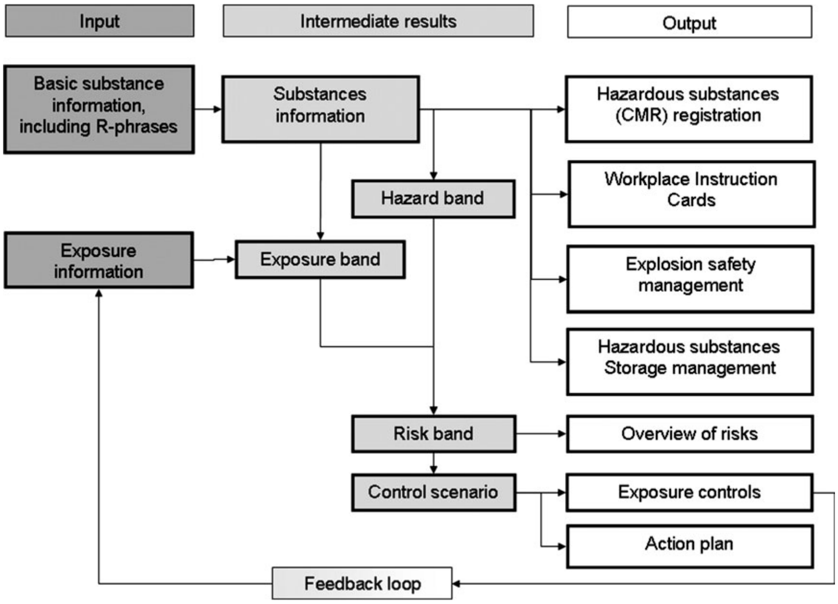

Fig. 1. Overview of Stoffenmanager, including risk banding and some other important elements.

when available. When no vapour pressure is mentioned for the product as a whole, but a vapour pressure for a main ingredient is given, that value can be entered. If no vapour pressure is available at all, the option 'unknown' has to be chosen. In that case, the vapour pressure of water at 20°C is chosen as default value.

A choice of 'dustiness' of the product has to be made by the user of the Stoffenmanager to allow the exposure model to take account of this parameter in establishing the exposure band (see later).

The input of the departments where the substance is used is needed to prepare the output of specific registration information for carcinogens, mutagens and reprotoxic agents.

Hazard banding

The hazard band of each substance is based on the R-phrases entered. For this purpose, the division of R-phrases in hazard bands of COSHH Essentials is used. The original hazard bands are described by Brooke (1998). A few modifications have been made since that publication to accommodate changes in the European Directives. An overview of the hazard bands can be found in the documentation on COSHH Essentials at http://www.coshh-essentials.org.uk.

Exposure banding

The exposure model used for exposure banding in the Stoffenmanager is based on the ideas published by Cherrie *et al.* (1996) and further developed by Cherrie and Schneider (1999). These ideas are used and adapted in several ways. The resulting model used in the Stoffenmanager is discussed in the next part of this publication. The exposure model leads to a classification in one of four exposure bands.

Risk banding

The results from the hazard and exposure banding steps are combined in the Stoffenmanager to produce risk bands. The Stoffenmanager only provides a relative ranking of risks. No quantitative comparison between exposure levels and hazard levels is made because in the present version both exposure and hazards are only classified in relative bands. The result of the risk banding is therefore a 'priority band'. It was decided to make three priority bands because fewer bands would lead to too limited discrimination, while more bands would suggest more precision than warranted. The combination of hazard and exposure into priority or risk bands in the Stoffenmanager is presented in Fig. 2. The classification of situations into priority or risk bands is based on the bands of hazard and exposure. Allocation into risk bands was done in such a way that exposure to very high hazard substances, such as carcinogenic substances or substances that lead to respiratory sensitization, would lead to a high priority, unless the exposure was very limited (leading to medium priority). The intention is to ensure that these substances and their use and control are considered specifically and in more detail by the user and to encourage the substitution by less dangerous substances. Also, very high exposures should generally lead to high priority, unless the hazard of the substances is very low. The further allocation was done to ensure a generally increasing risk band with increasing combination of exposure and hazard. Final allocations were, of course, partly arbitrary.

Exposure band \ Hazard band	A	B	C	D	E
1	3	3	3	2	1
2	3	3	2	2	1
3	3	2	2	1	1
4	2	1	1	1	1

Fig. 2. Priority bands in the Stoffenmanager. Hazard: A = lowest hazard and E = highest hazard. Exposure: 1 = lowest exposure and 4 = highest exposure. Overall result: 1 = highest priority and 3 = lowest priority.

When all situations within a company with exposure to substances have been assessed, the total overview of the risk banding for all these substances and situations provides a semi-quantitative risk assessment for the whole company.

Control scenario

When a situation is evaluated and a priority band is assigned, Stoffenmanager enables the user to design a risk reduction scenario or control scenario. This option leads to a list of possible control measures that can be taken. To guide the user towards control measures that are expected to ensure the best reduction, the control measures are presented in the order of the so-called 'STOP-principle' (substitution, technical measures, operational measures, personal protection). The user first has to consider the possible control measures of the first group, before he can go on to the control measures of the second group, etc. The following (generic) control measures can be chosen in the system in the order as indicated:

1. control measures at the source
   - removal of the hazardous product from the task
   - removal of the task from the process
   - modification of the product form
   - modification of the task, e.g. instead of 'frequent handling' the task can be modified to 'handling in closed systems'
   - replacement of the product by another product with a different composition, changing the hazard and possibly also the exposure
   - automation of the process, leading to a whole new exposure assessment
   - changing the order of tasks, e.g. adding powder to liquid instead of the other way around
2. control measures in an area directly around the source
   - placing the source in a containment in the room (full enclosure)
   - adding local exhaust ventilation to emission sources
   - combination of local exhaust ventilation and full enclosure
   - limiting the emission of a product (e.g. wetting powder)
3. modifying controls in the wider work area of the worker
   - creating and ensuring natural ventilation
   - installing a (mechanical) area ventilation system
   - use of a spray cabin
4. control of the situation of the worker
   - use of work cabins (with or without ventilation with clean air supply)
   - use of PPE

Depending on the choice of control measure, some of the inputs need to be re-evaluated to adapt the hazard or exposure bands for the chosen control measures. The new priority band is then calculated based on the modified inputs.

Because the exposure model leads to a classification into exposure bands, it is possible that a control measure that will lead to a reduction in exposure will not lead to a lower exposure band (and related priority band). In such cases, this is reported in the results of the control scenario and the user is recommended to consider implementing the control measure, even if it may not lead to a lower priority band.

Action plan

The modified inputs of a control scenario can be saved in an action plan. The tool itself does not choose the control measures. The choice of the control measures that a user wants to put in the action plan is up to the user. The tool will indicate whether these control measures have an effect on the priority band of the situations. There is an option to download the information into a document including elements to be filled in locally, e.g. who is responsible for the action, the estimated costs and the deadline for finalizing the action.

Workplace instruction cards

For all products, Stoffenmanager can generate so-called workplace instruction cards. This is a more readable and more user-friendly version of the information taken over from the SDS. In addition, the user has to specify the PPE, storage instructions and control measures in the case of accidental spillage.

Registration of carcinogenic, mutagenic and reprotoxic substances

There are specific legal requirements in The Netherlands for registering the carcinogenic, mutagenic and reprotoxic substances used in the workplace. This includes the number of workers exposed, the amount of the substance available in the workplace and the type of activities done with the substance. When a carcinogenic, mutagenic or reprotoxic substance is entered into the Stoffenmanager, the user can add this information in his data set to build up a registry of such substances. The user is also asked to indicate the control measures used to control exposure and the reasons why this substance cannot be substituted or removed from the process. This registry can be used to have a quick overview of the situation regarding these substances and to show to the authorities when required.

Information for the storage of dangerous substances

Information and guidance regarding the storage of dangerous substances in accordance to the guidelines in The Netherlands can also be entered and evaluated through the Stoffenmanager. This will not be discussed further in the present publication.

Explosion safety

Stoffenmanager also enables the user to assess explosion risks in the workplace (according to the European ATEX guidelines) and to choose control measures which can be transferred to an action plan. This module will not be discussed further in the present publication either.

EXPOSURE MODEL IN THE STOFFENMANGER

The exposure model used for the classification into exposure bands is based on a model presented by Cherrie and Schneider (1999), which was based on earlier work by Cherrie *et al.* (1996). The exposure algorithm follows a source-receptor approach and incorporates modifying factors related to source emission and dispersion of contaminants. Exposure is represented as a multiplicative function of type of handling, intrinsic properties of the product, local controls and general ventilation.

Cherrie *et al.* (1996) have made categories, running from 'none' to 'very high' for each parameter and given these categories a score on a logarithmic scale, running from 0 through 0.03, 0.1, 0.3, 1 and 3 to 10. A score of 1 is considered to be the default value that leads to a certain concentration. Values >1 indicate situations with increased exposure and values <1 situations with reduced exposure. A logarithmic scale for categories leads to a reasonable dispersion of resulting exposure levels or scores over the categories, in accordance with the logarithmic distribution that exposure levels often are found to have.

The model presented by Cherrie and Schneider (1999) has been modified on a few points to build a model that is suitable for use by SME employers, who are non-experts in occupational hygiene. Modifications have been made regarding the emission scores. New descriptions have been made for types of handling to make the descriptions more easily understandable and assignable by non-experts. The intrinsic emission scores have also been modified to enable a more user-friendly relation between type of product and intrinsic emission. Also, the emission of near-field and far-field sources was made the same to simplify the algorithms. Finally, a fixed background factor was added. Details of the final model are presented below.

A source of emission that is relatively far from a worker has a lower influence on the exposure of the worker than a source very close to the worker. Cherrie and Schneider (1999) have therefore distinguished the 'near-field' emissions, which take place very close to the worker, from the 'far-field' emissions that occur further away from the worker. They also present a separate equation for the far-field sources. They define the near field as a cube around the head of the worker with dimensions of 2 × 2 × 2 m. A source is inside the near field according to the Stoffenmanager if it is within a distance of 1 m from the head of the worker. This defines the near-field as a sphere instead of a cube. Because the main purpose of the Stoffenmanager is to rank situations relative to their risk, an additional factor was added for frequency and duration of the task. The categorization of parameters and the allocation of scores for categories in the Stoffenmanager are partly taken from the work by Cherrie *et al.* (1996). Where categories or definitions have been changed from the published versions, the final allocations were largely made by expert judgement.

The modified model as used in the new version of the Stoffenmanager is represented by the following equations:

$$B = C_t \times t_h \times f_h \qquad (1)$$

$$C_t = \left(C_{\mathrm{ds}} + C_{\mathrm{nf}} + C_{\mathrm{ff}}\right) \times \eta_{\mathrm{imm}} \qquad (2)$$

$$C_{\mathrm{ds}} = E \times a \qquad (3)$$

$$C_{\mathrm{nf}} = E \times H \times \eta_{\mathrm{lc}} \times \eta_{\mathrm{gv\_nf}} \qquad (4)$$

$$C_{\mathrm{ff}} = E \times H \times \eta_{\mathrm{lc}} \times \eta_{\mathrm{gv\_ff}} \qquad (5)$$

The final equation of the exposure model of Stoffenmanager is

$$B = \Big[\Big(E \times H \times \eta_{\text{lc\_nf}} \times \eta_{\text{gv\_nf}}\Big) + \Big(E \times H \times \eta_{\text{lc\_ff}} \times \eta_{\text{gv\_ff}}\Big) + \Big(E \times a\Big)\Big] \times \eta_{\text{imm}} \times t_h \times f_h \quad (6)$$

where B = exposure score; C_t = total concentration (score); t_h = duration of the handling; f_h = frequency of the handling; C_{ds} = background concentration (score) due to diffusive sources; C_{nf} = concentration (score) due to near-field sources; C_{ff} = concentration (score) due to far-field sources; η_{imm} = multiplier for the reduction of exposure due to control measures at the worker; E = intrinsic emission score; a = multiplier for the relative influence of background sources; H = handling (or task) score; η_{lc} = multiplier for the effect of local control measures; $\eta_{\text{gv\_nf}}$ = multiplier for the effect of general ventilation in relation to the room size on the exposure due to near-field sources and $\eta_{\text{gv\_ff}}$ = multiplier for the effect of general ventilation in relation to the room size on the exposure due to far-field sources.

Of course, SME employers are not able to use the equations presented above. Therefore, each of the parameters was specified in relatively simple options to create a useful model.

Intrinsic emission

Intrinsic emission ['E' in equations (3) to (6)] is a substance related parameter in the exposure model of the Stoffenmanager. It relates to the vapour pressure of liquids and the dustiness of powders.

For liquids, E is directly related to the vapour pressure. This continuous factor is chosen to be the same as the evaporation factor used in the 'AWARE' code (Krop and van Broekhuizen, 2006). This code has been developed in The Netherlands in the scope of the so-called VASt programme to assist companies in choosing products with lower risks.

The intrinsic emission is calculated as

$$E = P_{\text{product}}/30\,000 \quad (7)$$

where E = the intrinsic emission for a product and P_{product} = the vapour pressure of the product (Pa).

The idea behind this calculation is that E represents a relative evaporation factor. Substances with a vapour pressure of $\geq$30 000 Pa are fully evaporated in a very short time and will practically only be available as vapour. Substances with lower vapour pressures evaporate relatively slower and more of these substances may be present in the form of liquid product, therefore not being available for inhalation. The vapour pressure of a product can be derived in different ways. If available, e.g. on the SDS, the vapour pressure of the product itself can be used. If the liquid part of a product largely consists of one substance, the vapour pressure of that substance can be used. This could e.g. be done for a paint product where the only hazardous substance mentioned on the SDS is a mineral spirit with a weight percentage of 20–50% in the paint. The vapour pressure of this substance can be used as such ($\sim$350 Pa) to calculate the relevant emission factor weighted by the percentage of that substance in the product. If a product contains two or three volatiles that make up large parts of the product, one could derive a 'percentage weighted' intrinsic emission of the product according to equation (8).

$$E = (P_1/30\,000)f_1 + (P_2/30\,000)f_2 + (P_3/30\,000)f_3 \quad (8)$$

where P_i = the vapour pressure of substance i and f_i = the fraction of substance i in the product.

For a product with mineral spirits with a vapour pressure of 350 Pa in a concentration of 15% and naphtha with a vapour pressure of 690 Pa in a concentration of 30% and no other volatile substances, the calculated intrinsic emission to enter into Stoffenmanager would be (350/30 000)0.15 + (690/30 000)0.30 = 0.00865. It is recognized that, ideally, the mole fraction of a substance in a mixture should be used instead of a mass fraction. In general, however, there is only limited information on characteristics of the mixture available. For pragmatic reasons, we therefore rely on less precise but more accessible information.

Finally, if the above presented methods are not possible or not practicable, the vapour pressure can be presented as unknown in which case the value for water at 20°C (2300 Pa) will be used. This default is chosen from a conservative point of view, since it is unlikely that the vapour pressure of the critical compound in the mixture will be higher than the vapour pressure of water.

When the Stoffenmanager is used to prioritize exposures for single components from products, the intrinsic emission for the single substance can be calculated as

$$E_i = (P_i/30\,000) \times f_i \quad (9)$$

where E_i = the intrinsic emission for a specific component in the product; f_i = the fraction of the specific component in the product and P_i = the vapour pressure of the pure substance (Pa).

For dustiness of solids (powders), no direct relation with physical parameters is at hand. In analogy to the Cherrie model, a table with weighing factors for different descriptions of dusts was developed. The user will have to determine this parameter himself by comparing the observed dustiness with the descriptions of the categories of dusts in the Stoffenmanager. The scores for intrinsic emission of solid substances are presented in Table 1.

Table 1. Scores for intrinsic emission of solids

Intrinsic emission parameter	Explanation	Score
Solid objects	Solid forms of substances or products, such as blocks, kegs or slabs	0
Firm granules or flakes	For example, firm polymer granules, granules covered with a layer of wax, bound fibres, such as in cotton. No dust emission without intentional breakage of the product	0.01
Granules or flakes	Granules or flakes that may fall apart and crumble. For example, washing powder, sugar or fertilizer	0.03
Coarse dust	A dust cloud is formed, but settles quickly due to gravity. For example, sand, coarse carbon black, calcium stearate, unbound fibres	0.1
Fine dust	A dust cloud is formed that is clearly visible for some time. For example, talcum powder, flour	0.3
Extremely dusty products	A visible dust cloud remains airborne for a long time	1

Handling

The scores for handling ['*H*' in equations (4) to (6)] are related to a number of processes that may influence emission. These processes can be described in physico-chemical terms, such as evaporation, frictional forces, etc. In a specific model for a specific set of tasks, e.g. in a branch-specific Stoffenmanager, the handling can be described in detail in a language understandable to SME employers. This is much more difficult in a generic model. Descriptions and discriminating categories, that are expected to be understandable to the user of the model, were made to capture these exposure processes. The scores for handling are described in Table 2 for liquids and in Table 3 for solids.

Near-field and far-field sources

A source is considered to be in the near field ['nf' in equations (2), (4) and (6)] if it is within 1 m of the head of the worker. A far-field source ['ff' in equations (2), (5) and (6)] is made recognizable to users by asking whether other workers in the room are doing the same task or whether there is a period of evaporation, hardening or drying of products on a surface (after application) that is left in the work area of the worker. To simplify the model, it is assumed that the same handling is conducted in the far field as in the near field. In addition, no distinction is made between one or multiple co-workers in the far-field or continuous presence of co-workers versus presence during only part of the time. The emission of a far-field source due to a period of evaporation, hardening or drying will be restricted to products with a vapour pressure $>$10 Pa.

Reduction of transmission

Reduction of transmission from the source towards the worker is possible in several ways. In the Stoffenmanager, this is split into two factors: local control measures [η_{lc} in equations (4) to (6)] and general ventilation [η_{gv} in equations (4) to (6)]. Both can have different options for near-field and far-field sources, as indicated by $\eta_{lc.nf}$ versus $\eta_{lc.ff}$ in equations (4) to (6). However, to simplify the model, it is assumed that the same local controls are used for near-field and for far-field sources. The scores for local controls used for near-field and far-field sources are presented in Table 4. The scores for general ventilation are different for near-field and far-field sources. These scores are related to the room volume and are taken from Cherrie (1999), who based the values on simulations. They are presented in Tables 5 and 6.

Background emissions

The far-field sources can be distinguished by the answers to the questions in the Stoffenmanager on co-workers doing activities with the same substance or product and on emission due to evaporation, hardening or drying of a substance or product after application. However, there can also be sources dispersed through the work area that are not covered by these questions. Such sources can be leaking machinery, contaminated rags lying around the room, spills that have not been cleaned up, etc. Therefore, an additional factor was added for background emissions in the model [C_{ds} in equations (2) and (3)]. In the model, it is a basic assumption that the exposure (and the background sources) has to be related to the intrinsic emission of the product. Therefore, it was decided to use a factor directly related to the intrinsic emission factor [a in equation (3)]. In this way, the background emission of high volatile substances would be higher than that of low volatile substances. A (small) factor is defined, dependent on the regularity of inspection of machines and on the cleaning procedures in the work area. The scores are presented in Table 7. By using the background emissions through a small additional emission factor, its influence is insignificant for activities with high direct emissions, but becomes more apparent when there are hardly any direct emissions as seen from the handling scores. As the impact of diffusive sources on exposure level is extremely difficult to predict, we decided to keep this part of the equation as simple as possible. Therefore, a general ventilation parameter was not incorporated in the diffusive source component.

Table 2. Scores for handling of liquids

Description	Examples	Score
Handling of liquids in tightly closed containers	Transport/shifting of closed containers	0
Handling of liquids where only small amounts of product may be released	Measuring doses using a dose-measuring device	0.1
	Handling of small quantities in laboratory situations, like using pipettes	
Handling of liquids at small surfaces or incidental handling of liquids	Gluing of stickers and labels	0.3
	Cleaning of small objects like knives	
	Cementing	
	(Un)coupling of tank lorries or (dis)connecting of production lines	
Handling of liquids using low pressure, low speed and on medium-sized surfaces	Mixing/diluting of liquids by stirring	1
	Manually drawing off or pouring of product	
	Painting of casings using a roller or brush	
	Gluing larger pieces together, e.g. shoe soles	
	Degreasing or cleaning small machines/tools/work pieces/tanks, etc.	
	Immersion of small objects in bucket with cleaning agent	
Handling of liquids on large surfaces or large work pieces	Painting of walls or ships with a roller or brush	3
	Degreasing of large machinery	
	Gluing or cleaning of floors	
	Handling of heavily contaminated tools/objects or packages	
	Handling of immersed objects, handling of painted objects	
	Mechanically immersing of large objects in an immersion bath, for example for cleaning purposes	
Handling of liquids (using low pressure but high speed) without creating a mist or spray/haze	Foaming a product for cleaning or coating purposes	3
	Mixing of products under high velocity using a mixer	
	Uncontrolled pouring of a liquid from a large height, for example pouring of production flows	
	Use of metalworking fluids like lubricants during cutting, sanding or drilling activities	
Handling of liquids at high pressure resulting in substantial generation of mist or spray/haze	Spraying of product (using high-pressure or spray painting)	10
	Fogging a product producing a visible mist	
	Opening a (pressurized) production line for taking samples or opening a closed cleaning device to remove cleaned objects	
	Opening of a closed system where products are treated/present at high temperature or pressure	
	Activities in the direct vicinity of open baths (high process temperature, cooking liquid)	

Modification for reduction of immission and duration and frequency of the task

The score that is obtained by summing up the three elements of emission (near-field, far-field and background) is corrected for the reduction of immission ['η_{imm}' in equations (2) and (6)]. The reduction of immission in this model can be accomplished by means of separating the worker from the source or by using PPE. The first measure is slightly different from segregating the source from the worker. Instead of putting a source in a specific room, the workers are put in a specific room (e.g. a control room) for most of their working day. They only enter the area where the real production takes place for specific activities. The worker can also be placed in a closed cabin (e.g. in a tractor cabin while spraying pesticides). The scores for reduction of immission are presented in Table 8.

Another option to limit immission is the use of PPE. For this purpose, the assigned protection factors as presented in a document of the Dutch Occupational Hygiene Society on selection and use of respiratory protection were used as a basis (NVvA, 2001). These scores are presented in Table 9.

Table 3. Scores for handling of solids

Description	Examples	Score
Handling of products in closed containers	Transport/shifting of barrels or plastic bags	0
Handling of product in very small amounts or in situations where release is highly unlikely	Shifting of packages of which the seams are not dustproof	0.1
	Weighing a few grams of product	
Handling of product in small amounts or in situations where only low quantities of product are likely to be released	Moving of polluted/dirty packages	0.3
	Weighing several hundreds of grams of product	
	Shifting of cement bags or sackcloth bags with product with a forklift truck	
	Kneading of paste	
Handling of product with low speed or with little force in medium quantities	Producing cement wet mortar using a chip	1
	Producing cement manually with a shovel	
	Handling small or light materials externally contaminated with a substance (for example collecting and piling up of cement bags)	
	Manual weighing of kilogram amounts of products for recipes (for example in the animal feeds or textile industries)	
Handling of products or treatment of objects with a relatively high speed/force which may lead to some dispersion of dust	Manual dumping, relatively small scale	3
	Manually scattering/strewing of the product	
	Sweeping a floor	
	Mixing of products with a mixer	
	Dumping of powders with a pipe	
	Manually scooping of products (high control level)	
	Manually handling of treated or contaminated products/materials (for example rubber parts are treated with anti-stick powder)	
	Manual sawing, boring, sanding, polishing, etc.	
Handling of products or treatment of objects, where due to high pressure, speed or high force, large quantities of dust are generated and dispersed	Spraying of powders (powder coating)	10
	Dumping of product from big bags	
	Bagging of product	
	Dumping of bags, large scale	
	Cleaning of contaminated machines or objects with compressed air	
	Machine sawing, boring, sanding, polishing, etc.	

The Stoffenmanager prioritizes separate tasks with products, based on the exposure related to the product and the task and the hazards related to the products. Some tasks may occur only a part of the work shift. This is accounted for by modification of the exposure score based on duration of the task during a working day and frequency of the task (year based). The calculated exposure score is based on the assumption that a task is being performed during 8 h a day with a frequency of 5 days per week (totally 40 h per week). In this situation, the factor 'duration times frequency of task' is 1. If a task is being performed during fewer hours per day and/or in a lower frequency than 5 days per week, a linearly proportional reduction of the factor duration times frequency of task is used. In practice, task duration and exposure duration may not be the same. A concentration of a contaminant in workroom air may be reduced slowly due to limited ventilation. However, it was decided that it would make the model too complicated if this kind of effect was to be taken into account specifically. Again, we have decided for user-friendliness at the loss of some precision. The scores for duration and frequency of exposure are presented in Tables 10 and 11.

The modification of the scores obtained from the three emission sources by taking into account the reduction of immission, the duration and the frequency of exposure leads to a final exposure score. This exposure score is not used directly because the score

Table 4. Scores for local controls

Criteria	Explanation	Score
Containment of the source with local exhaust ventilation	Containment of the source in combination with local exhaust ventilation, e.g. a fume cupboard	0.03
Containment of the source	The source is fully contained, however, no local exhaust ventilation is used within the containment	0.3
Local exhaust ventilation	Removal of air at the source of the emission. The dangerous substances are captured by an air stream leading them into a hood and duct system	0.3
Use of a product that limits the emission	For example, wetting a powder, spraying of water	0.3
No control measures at the source		1

Table 5. Scores for reduction by general ventilation for near-field sources, dependent on room size

Room size (volume)	No general ventilation	Mechanical/ natural ventilation	Spraying booth
Volume <100 m^3	10	3	0.1
Volume 100–1000 m^3	3	1	0.3
Volume >1000 m^3	1	1	1
Work is done outside	—	1	—

Table 6. Scores for reduction by general ventilation for far-field sources, dependent on room size

	No general ventilation	Mechanical/ natural ventilation	Spraying booth[a]
Volume <100 m^3	10	3	0
Volume 100–1000 m^3	1	0.3	0
Volume >1000 m^3	0.3	0.1	0
Work is done outside	—	0.1	—

[a]When tasks are performed inside spray cabins, it was decided that exposure due to a far-field source was unlikely.

itself is not an exposure level and because using the scores directly for ranking situations would suggest more precision than is warranted with a tool like this. Therefore, the final exposure scores have been assigned to exposure bands according to Table 12.

FURTHER DEVELOPMENTS OF THE STOFFENMANAGER

A number of future developments of the Stoffenmanager is presented below to indicate what increase in usefulness of the tool is expected soon.

Branch-specific versions

The present Stoffenmanager is a generic tool for use in all kinds of companies. It is therefore not tailored to specific needs of specific branches. Stimulated by the VASt programme, several branches, including artists, surface treatment (metal), cleaning, metal fabrication and engineering industry, construction industry (sub-sectors plastering and tiling), dentistry, textile and carpet manufacture, flooring and carpet laying industry have started to develop their own version of the Stoffenmanager, usually based on the previous version of the Stoffenmanager. These branch-specific tools will be made available only to companies in the branch. The branch-specific tools can have specific modifications that may include

1. using default tasks for the parameter ‘handling’
2. a list of default control measures for specific tasks
3. using known reduction factors to evaluate the effectiveness of control measures
4. quantification of exposure levels for certain tasks based on measured values
5. an integrated product database to allow easy input of basic product data,
6. branch-specific hazard bands for toxic substances released during a process
7. a branch-specific risk banding system for skin exposure

A general feature of the branch-specific versions is that the language of the tool is tailored to the terminology of the branch.

Table 7. Scores for the multiplier for the relative influence of background sources

	No daily cleaning	Daily cleaning
No regular inspections and maintenance of machines and equipment	0.03	0.01
Regular inspections and maintenance of machines and equipment	0.01	0

Other developments

A number of other developments of the tool are already incorporated or planned for the (near) future:

1. Inclusion of fact sheets and PIMEX (Picture Mix Exposure) videos on exposure control measures (generic or branch specific).
2. Extraction of data from Stoffenmanager about products, their use and the control measures as (part of) exposure scenarios under REACH (http://ecb.jrc.it/).
3. Quantification of the exposure model of the Stoffenmanager using an extensive set of dedicated

Table 8. Scores for reduction of immission

Score	Reduction of immission parameter	Explanation
0.03	The worker is in a separated (control) room with independent clean air supply	The workplace of the worker is in a (control) room that is equipped with an air supply independent of the air in the room where the source is
0.1	The worker works in a cabin without specific ventilation system	For example in a cabin of a tractor or truck, a cabin not equipped with filters, overpressure system etc. or behind a screen
1	The worker does not work in a cabin	The employee is not protected from the source by using a cabin

Table 9. Scores for protection by PPE

Score	Type
1.00	None
	Dusts
0.40	Filter mask P2 (FFP2)
0.20	Filter mask P3 (FFP3)
0.40	Half mask respirator with filter, type P2L
0.20	Half mask respirator with filter, type P3L
0.20	Full face respirator with filter, type P2L
0.10	Full face respirator with filter, type P3L
0.20	Half/full face powered air respirator TMP1 (particulate cartridge)
0.10	Half/full face powered air respirator TMP2 (particulate cartridge)
0.10	Half/full face powered air respirator TMP3 (particulate cartridge)
0.05	Full face powered air respirator TMP3 (particulate cartridge)
0.20	Hood or helmet with supplied air system TH1
0.10	Hood or helmet with supplied air system TH2
0.05	Hood or helmet with supplied air system TH3
	Gases/vapours
0.40	Half mask respirator with filter/cartridge (gas cartridge)
0.20	Full face respirator with filter/cartridge (gas cartridge)
0.20	Half/full face powered air respirator TM1 (gas cartridge)
0.10	Half/full face powered air respirator TMP2 or 3 (gas cartridge)
0.20	Hood or helmet with supplied air system TH1
0.10	Hood or helmet with supplied air system TH2
0.05	Hood or helmet with supplied air system TH3

Table 10. Scores for duration of exposure

Score	Parameter
0.06	1–30 min a day
0.25	0.5–2 h a day
0.50	2–4 h a day
1.00	4–8 h a day

Table 11. Scores for frequency of exposure

Parameter	Score[a]
1 day a year	0.01
1 day a month	0.05
1 day per 2 weeks	0.10
1 day a week	0.20
2–3 days a week	0.60
4–5 days a week	1.00

[a]A combination of unrealistic combinations of duration and frequency, e.g. '>4 h per day' combined with 'two to four times per day' will be noted by the tool and the user will be asked to specifically confirm that this is indeed the combination that needs to be used.

Table 12. Assignment of exposure scores to exposure bands

Exposure band	Minimum exposure score	Maximum exposure score
1	0	0.00002
2	0.00002	0.002
3	0.002	0.2
4	0.2	20

measurements together with existing exposure data gathered from several sources (Tielemans *et al.*, 2008). The quantified version can e.g. be used in exposure assessments for REACH.

4. Validation of the quantified model with independent, newly gathered exposure data (J. Schinkel, W. Fransman, H. Heussen, H. Marquart and E. Tielemans, in preparation).
5. Development of a web-based exposure database to collate exposure data for calibration and improvement of the Stoffenmanager exposure model in the future (STEAMbase: STоffenmanager Exposure and Modelling database).

DISCUSSION AND CONCLUSIONS

The Stoffenmanager is an easy to use tool that plays an important role in the Dutch VASt programme. There are now >6600 registered users of the Stoffenmanager. After implementation of the branches-specific Stoffenmanagers, this number is expected to increase rapidly. This tool apparently fills a need in The Netherlands as is also shown by the development of several specific Stoffenmanagers for industry branches.

The Stoffenmanager is not the answer to all questions regarding risks of dangerous substances in SMEs. Presently, it is limited to prioritizing risks in a rather generic way, coupled with advice on general risk management measures and some other useful elements. It cannot fully fill all the needs of the rules for risk assessment at the workplace (e.g. the so-called Chemical Agents Directive 98/24/EC).

The usefulness of the tool depends on its validity, its outputs, as well as on its user-friendliness. The hazard banding part of the Stoffenmanager is the same as that of the widely accepted COSHH Essentials tool. The exposure model is different. It is based on published approaches (Cherrie and Schneider, 1999), including an evaluation of the processes from source emissions to exposures.

Some modifications to the approaches of Cherrie and Schneider (1999) were made. The handling scores are derived from more user-friendly questions. Substantial expert judgement was used to cluster and describe tasks in understandable groups and to allocate scores to the handling. Using more (examples) of handling descriptions increases the user-friendliness. A consistent allocation of intrinsic emission scores is probably facilitated by the use of our more understandable classes. We consider the changes in definition of near field of relatively limited influence. However, the fact that we give the same emission score and local control score to far-field sources as to the near-field source is a simplification that can have substantial implications. It is not always logical that work done by others in the same area is similar to the work done by the assessed worker. This may lead to both over- and underestimation of exposure band. Finally, the addition of a background factor is probably an improvement. It caters for situations where diffusive sources are very important and only influences situations with very limited handling related emissions.

Several of the boundaries between categories had to be chosen in a rather arbitrary manner because of a lack of information on the relation between the parameters and exposure levels. While some boundaries are clear-cut (e.g. room volumes), others are described only qualitatively (dustiness index) to allow non-expert users to use the tool with information that they have available. It is not possible to evaluate every boundary and every choice within such a tool in depth based on real exposure data.

The model has been evaluated with a rather large set of measured data and was shown to perform quite well. The evaluation showed Spearman correlation coefficients between Stoffenmanager scores and exposure measurements that appear to be good for handling solids ($r_s = 0.80$, $N = 378$, $P < 0.0001$) and liquid scenarios ($r_s = 0.83$, $N = 320$, $P < 0.0001$). Mixed effect regression models with natural log-transformed Stoffenmanager scores as independent parameter explained a substantial part of the total exposure variability (52% for solid scenarios and 76% for liquid scenarios) (Tielemans *et al.*, 2008). These results provide reassurance that the model overall performs quite well. The results cannot be used to evaluate the influence of single parameters or choices in scores.

The adequacy of the final priority bands for discriminating between situations with true risks and situations with adequate control is difficult to evaluate. A good relation between exposure scores and exposure levels is a positive starting point. However, the final adequacy also depends on the hazard bands and there is very limited information to indicate how well the categorization of R-phrases in hazard bands works. A future evaluation of the total adequacy of the Stoffenmanager could study what the relation is between the assigned priority band and the exceedance of occupational exposure limits.

An important wish of users of the Stoffenmanager is to enable its use for comparison of (quantitative) exposure levels with occupational exposure limits. The quantification described by Tielemans *et al.* (2008) enables such a comparison, although it is not yet integrated directly into the software of the tool. A further extension may be to directly improve the model estimates with measured exposure levels for the situation under study through a Bayesian method. Such a new modelling approach has been proposed by Creely *et al.* (2005). We are currently investigating the possibilities of this approach, both for a large-scale 'advanced exposure model' (Tielemans *et al.*, 2007) with a built-in exposure database as well as for a small-scale option for users to fill in a few own measurement results to improve on their own assessment.

Both the Ministry of Social Affairs and Employment and the industry invested a substantial amount of money and/or time in the development of the VASt programme and the development of the Stoffenmanager. The industry in The Netherlands is willing to improve the working conditions on dangerous substances, especially when this can be done in a pragmatic manner with useful tools. Due to its central position within the VASt programme, Stoffenmanager functions as a crystallization point for several other developments. In the future, other tools can be integrated in or linked to the Stoffenmanager (or its specific versions).

The development of several specific variants of the Stoffenmanager raises the question whether in the future all these variants can still be called 'Stoffenmanager'. Their internal engine may still be largely similar, but their outside skin and several specific elements may lead to very different tools. This is not a real problem, as long as the quality of the tools is ensured. Whether or not a tool is still a version of the Stoffenmanager is not a real issue; much more important is the fact that the development of the Stoffenmanager has facilitated a whole range of further developments of useful tools for SMEs.

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